evfiresafe.com

EV FireSafe

Enhancing safety for emergency responders at electric vehicle fires

Emma Sutcliffe, Project Director
Dan Fish, Technical Specialist

EVs & Emergency Response

Supported by:

Australian Government
Department of Defence

In partnership with:

DEAKIN UNIVERSITY

We're researching

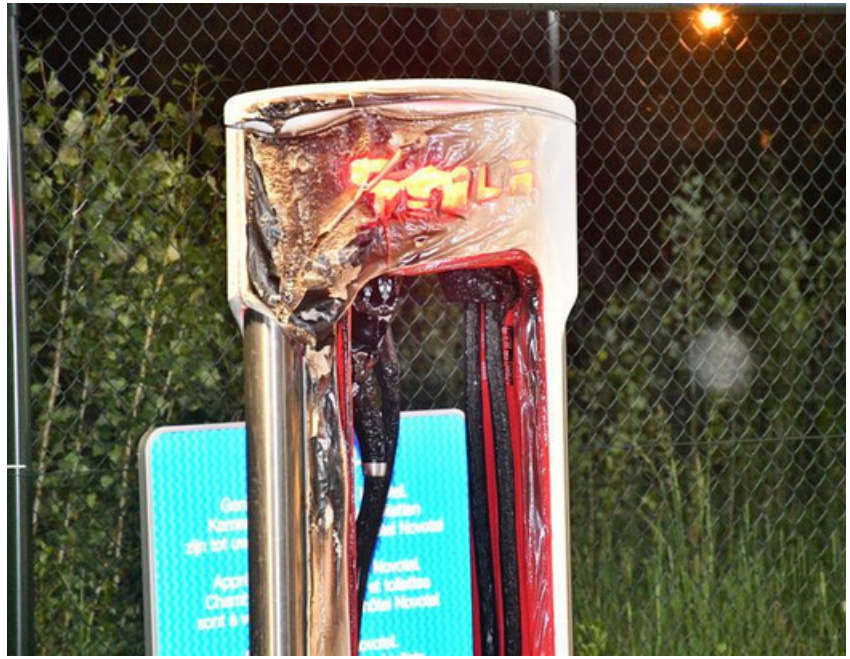
EV lithium ion battery fires

What do they mean for emergency responders?

+

connection to energised charging

What additional risks do emergency responders face?



NEW EV LiB FOR INVESTIGATION

2 November, 2022 - Klosterneuburg, Germany

1

bmw ix i4 fires

15 June, 2022 - Laos

BYD Song, 15 October 2022, China

4

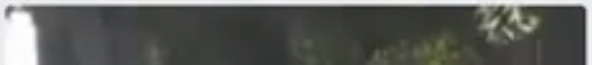
VERIFIED Passenger EV LiB FIRES (added to database)

1 May, 2012 - Fort Bend County, Texas, USA

2 3

26 May, 2012 - Shenzhen, China

1 1



Workshop / repair EV LiB Fires

NEW INCIDENT

2 March, 2019 - Surrey, England (Tesla Service Centre)

3 2

NEW INCIDENT

27 August, 2021 - Bonnevoie, Luxembourg (Tesla service centre)

3 7

e-B

E

25 J

E

16 M

Chir

E

27 S

Cou

EV FireSafe

Enhancing safety for emergency responders at *electric vehicle* traction battery fires

→ Welcome! Start here...

EV FireSafe is proudly supported by:

Australian Government
Department of Defence

With assistance from:

DEAKIN UNIVERSITY

EV FireSafe's global work

Research funded by:

Australian Government
Department of Defence

Our work is referenced by &/or we collaborate with:

Paul Christensen LITHIUM ION SAFETY
afac
METROPOLITAN FIRE SERVICE SOUTH AUSTRALIA
RI.SE
NFCC National Fire Chiefs Council
Ford
FIRE + RESCUE
SES
CFA
CTIF
TESLA
NIPV Nederlands Instituut Publieke Veiligheid
HYUNDAI

We are invited Technical Panel members for Fire Protection Research Foundation's (at the National Fire Protection Association, US), 2 year testing & training program:

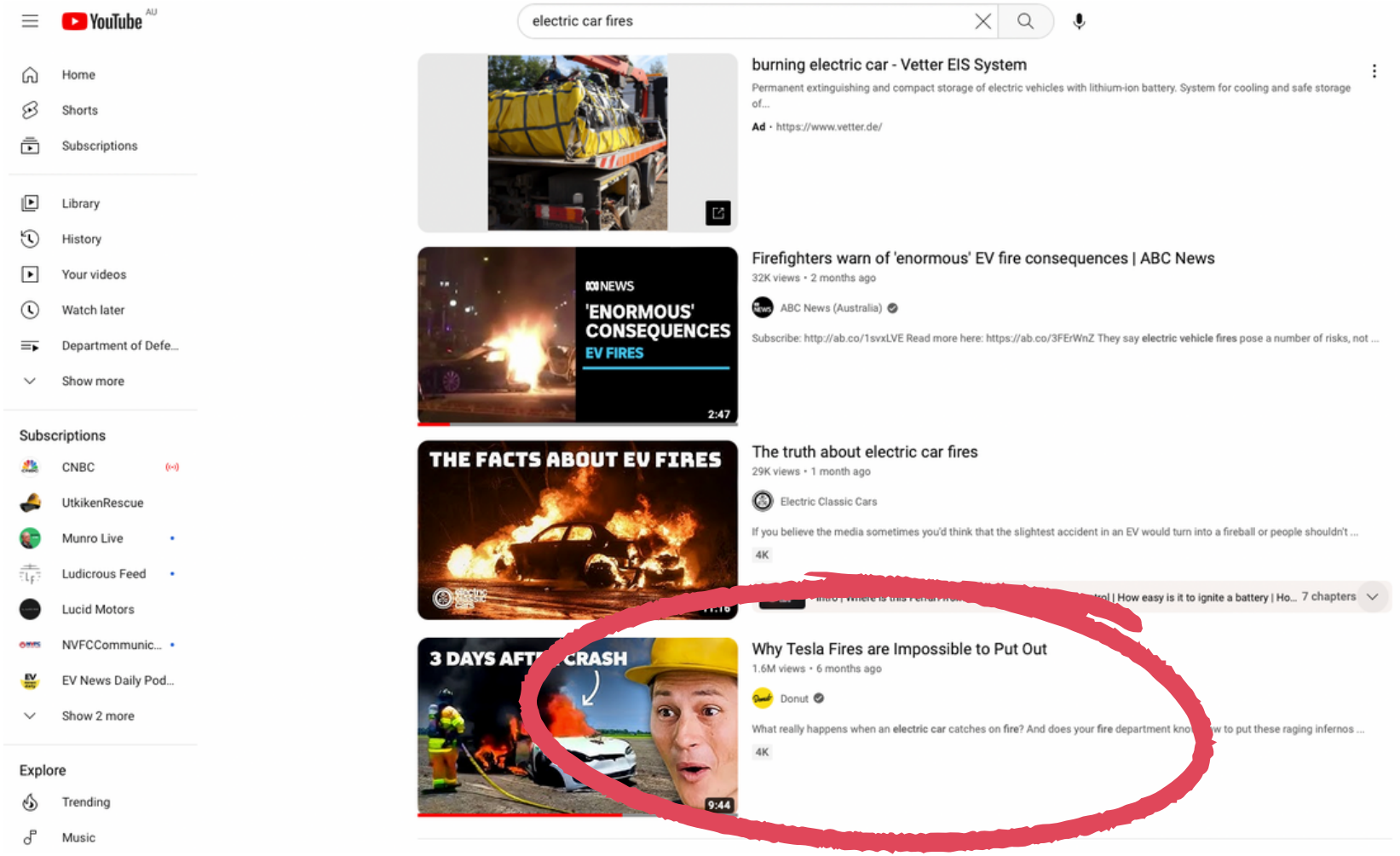
"Assessment of Electric Vehicle Firefighting Techniques, Technologies & the Impact of Stranded Energy"

ACT Fire Rescue's brand new e-truck

What does our data say?

(And does the FUD match?)

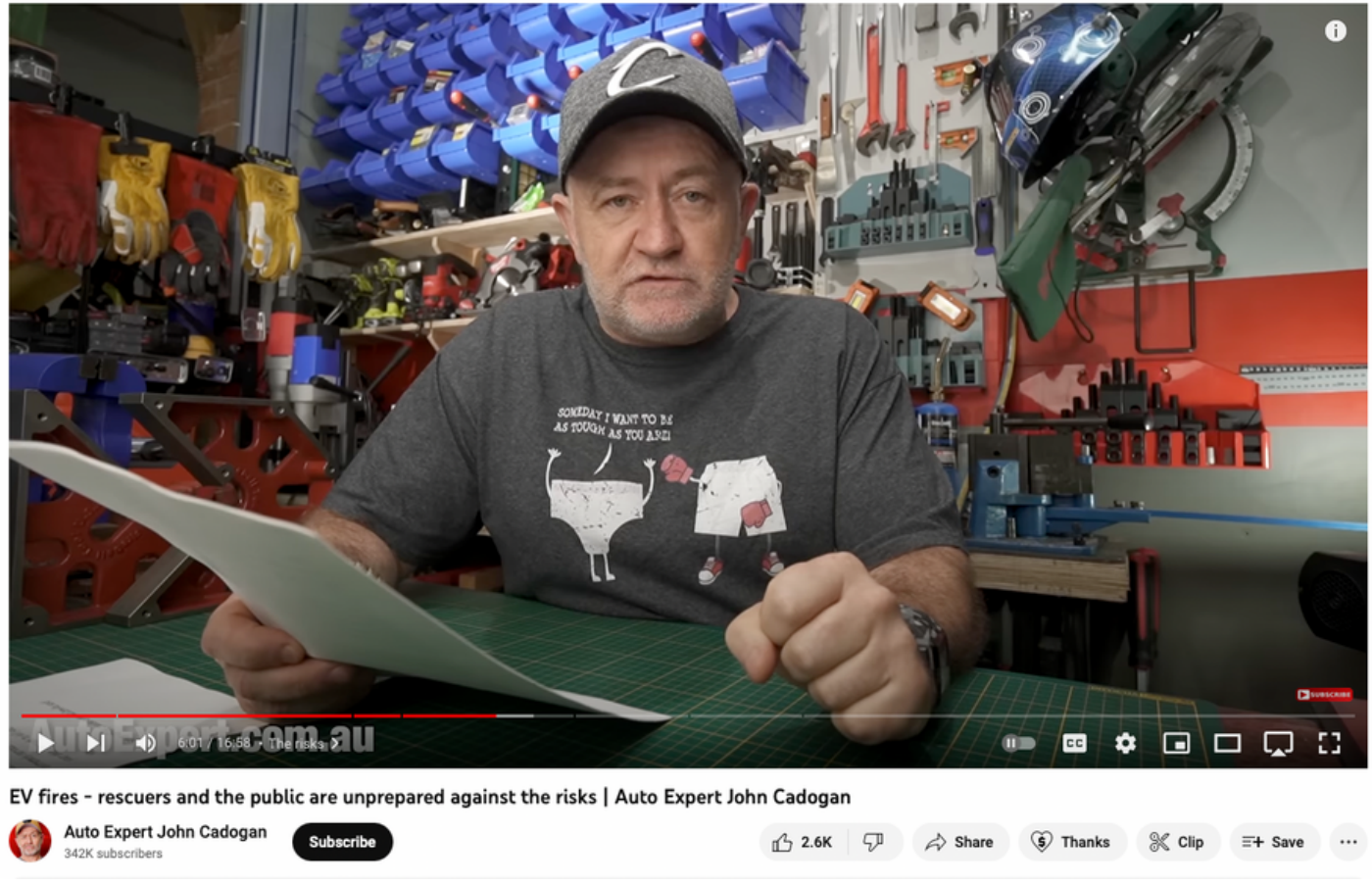
EV fires are ~~big news~~ clickbait



= 1.6m views

EV fires are ~~big news~~ clickbait

Misleading, unresearched information = 45k views



EV fires are ~~big news~~ clickbait

Widely reported statements by Firefighters Union ACT President

Mr McConville also said that the problem was not limited to EVs.

"Many homes are installing lithium batteries as part of their solar panel energy systems and BESS are being installed in underground carparks and in apartment blocks," he said.

Mr McConville added that thermal runaway fires released toxins which were dangerous to firefighters and the comm

BESS fires release an array of deadly toxins including Carbon M ide, Hydrogen Cyanide, Hydrogen Fluoride and Cobalt," he said.

"These toxins are especially dangerous to firefighters because they are der lly absorbed through the skin and no personal protective clothing can protect you against it.

Incorrect

Incorrect & misleading

Monoxide and Hydrogen Cyanide are known as the terrible twins. They t the body using oxygen and cyanide affects organs that rely on high levels of oxygen such as heart and the brain.

"We've already had a situation in Victoria where two firefighters suffered Cobalt poisoning after attending an EV fire, and have now been permanently disabled as a result.

e toxins also present a major risk to other emergency services personnel such as police and ambul fficers, bystanders and the broader community and as such, every possible mea must be undertaken to impact."

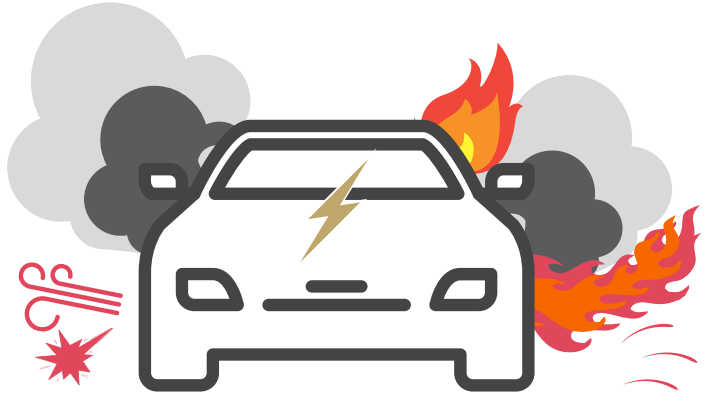
Mr McConville said that the increasing uptake of EV and BESS units meant Australia's governments needed to develop regulation, policy, training and education to cut risks.

EV LiB fires are very rare

In passenger plug-in EVs, we have verified*:

387 EV traction battery fires globally, 2010-today

+ 74 currently being cross checked



'In the world of clean energy, few areas are as dynamic as the electric car market. We estimate there are now **around 16 million electric cars** on the road worldwide...'

International Energy Agency, January 2022

7.8 million EVs were sold in 2022 alone...

Wall Street Journal, January 2023

*Not exhaustive. From more than one online source, interviews, first hand accounts, videos, images, academic & fire agency reports & online training

EV fires by year

Chevrolet Bolt & Hyundai Kona recalled due to battery fault during manufacture

38

125
100
75
50
25
0

2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

evfiresafe.com

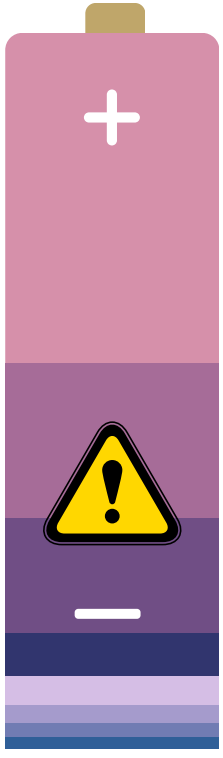
EV fires by manufacturer

Most number of EVs
on the road
Most number of
'collision at speed'

150
100
50
0

Tesla
Hyundai
Chevrolet
BMW
Renault
Unknown
Nissan
Porsche
Jaguar LR
Mitsubishi
VW
BYD
Fisker
Mini
Audi
Peugeot
Lucid
NIO
Xpeng
Chery
Chrysler
Ford
GWM
Huawei
Lordstown
GAC Aion
Fiat
Dongfeng
ARK
BAIC
Lincoln
NIO

Causes of battery cell abuse

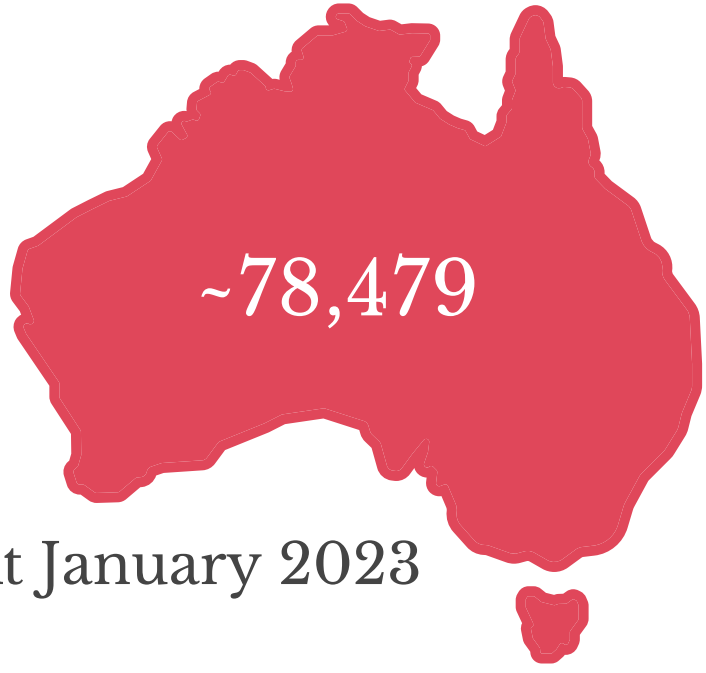


Unknown	49%
Collision / debris	22%
OEM fault	12%
Submersion	6%
Arson / malicious	3%
External fire	3%
Repair / workshop	2%
Overheating / electrical	2%
Manufacturing defect	0.5%
Human error	0.5%

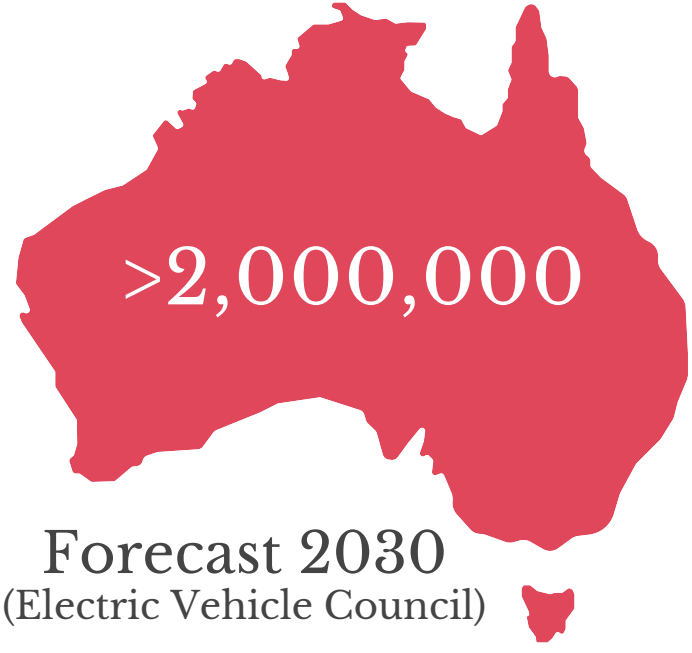
*Data current January 2023
^Percentage of incidents EVFS studied

EVs in Australia

EV ownership* is concentrated in capital & major cities, but there are now EVs in every Australian region



At January 2023

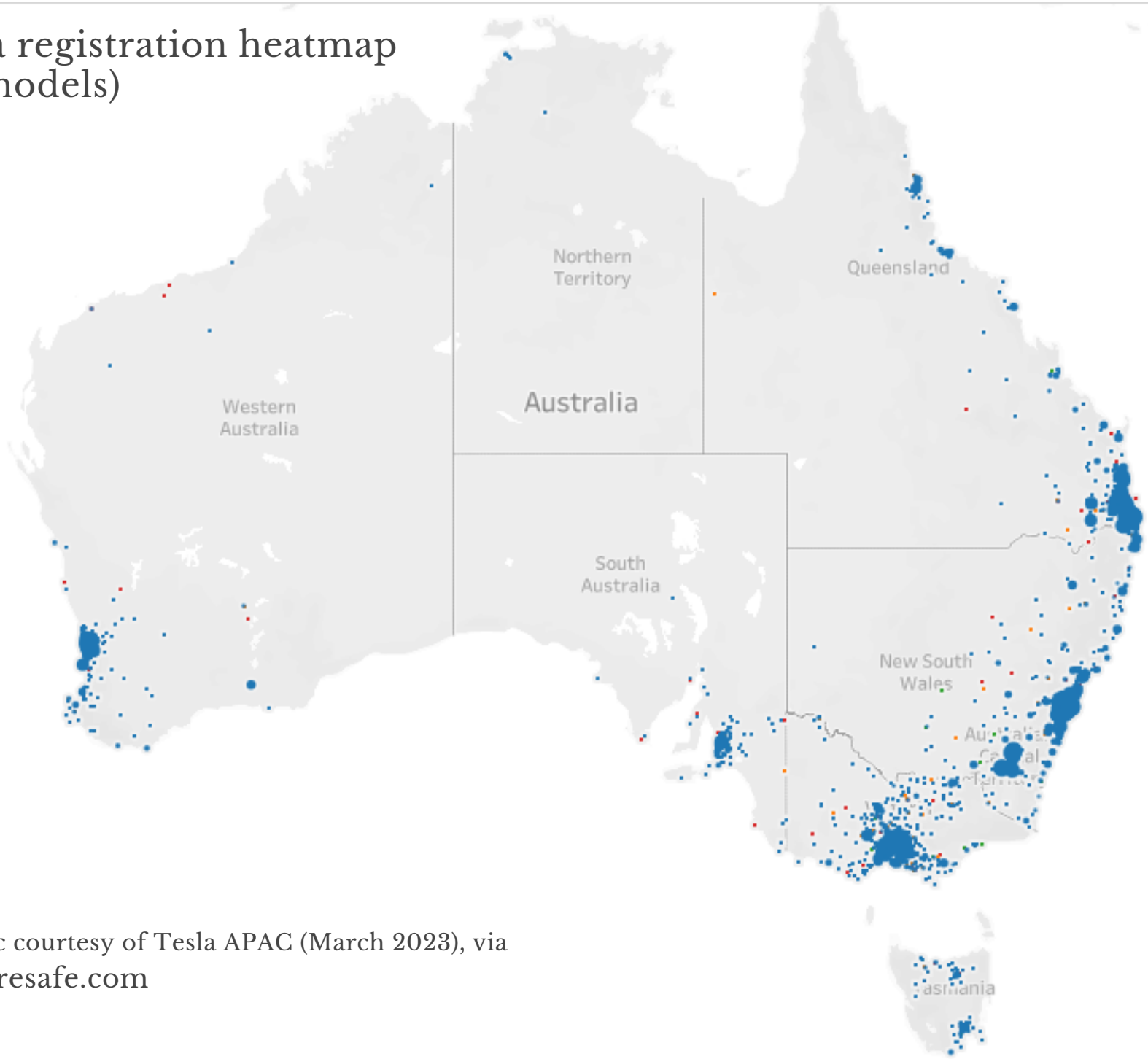


Forecast 2030
(Electric Vehicle Council)

~70%

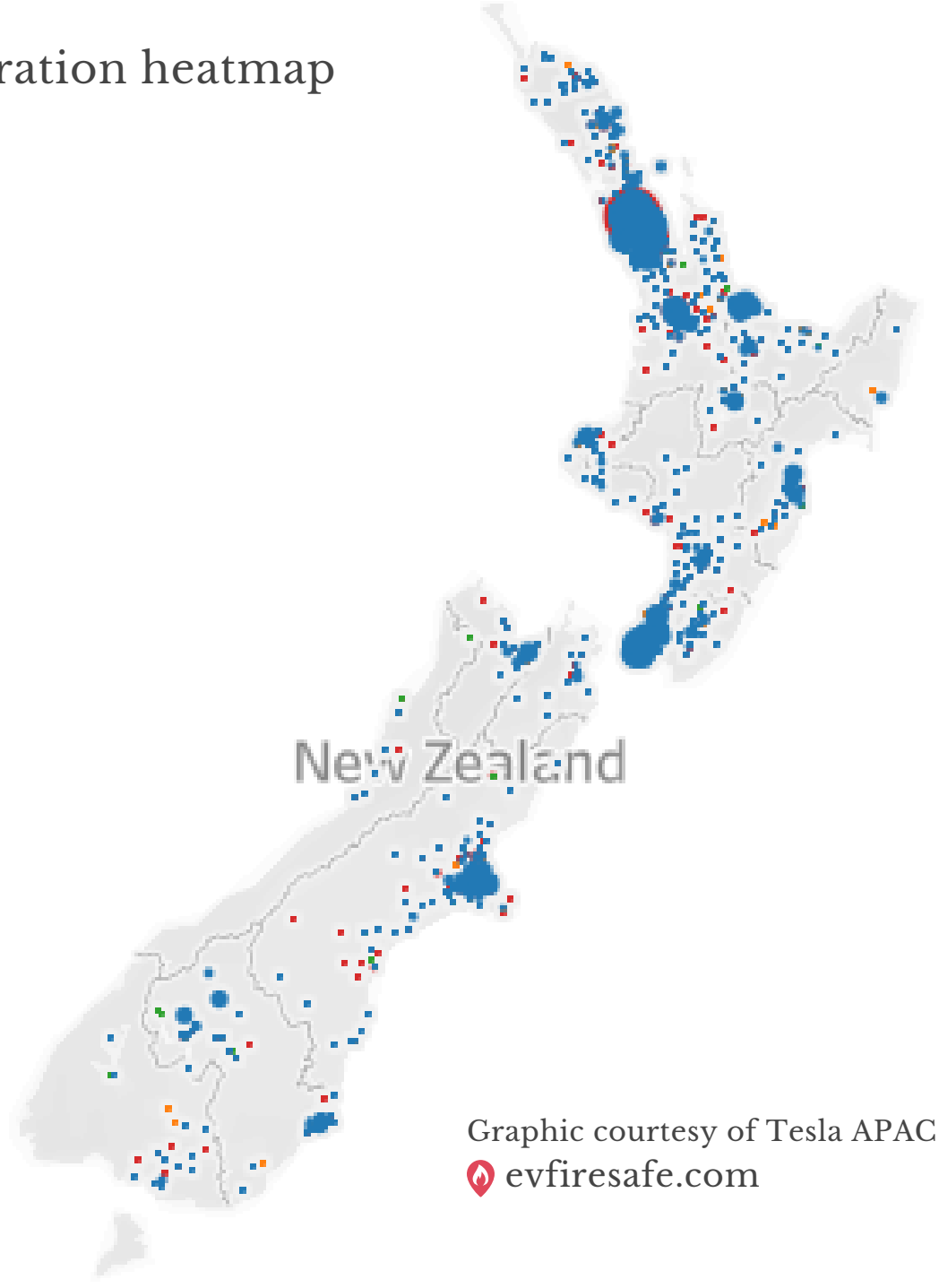
compound annual growth rate of EVs since 2010

Tesla registration heatmap (all models)



Graphic courtesy of Tesla APAC (March 2023), via
evfiresafe.com

Tesla registration heatmap (all models)



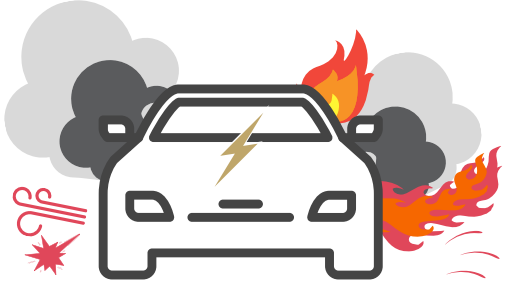
Graphic courtesy of Tesla APAC (March 2023), via evfiresafe.com

What about other EV types?

From 1st Jan 23, we started tracking
BEB, BET & LEV

EV comparison for Q1 2023

Passenger EVs



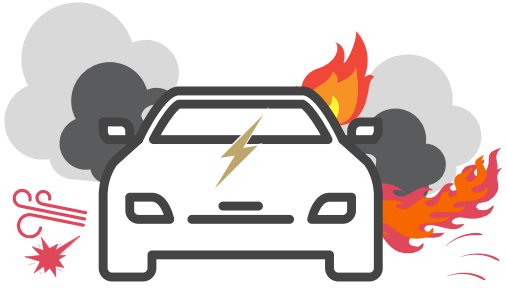
23
Battery fires

8
Injuries

4
Fatalities

EV comparison for Q1 2023

Passenger EVs

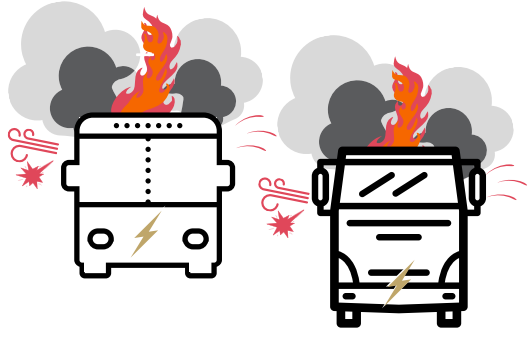


23
Battery fires

8
Injuries

4
Fatalities

Electric buses & trucks



2
Battery fires

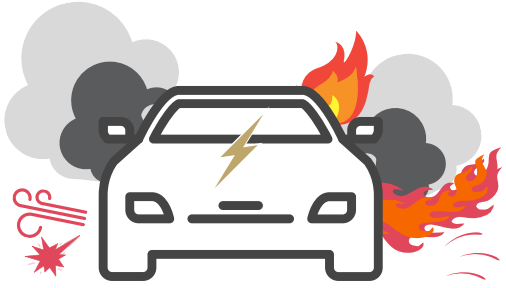
0
Injuries

0
Fatalities

1
Battery fire

EV comparison for Q1&2 2023

Passenger EVs

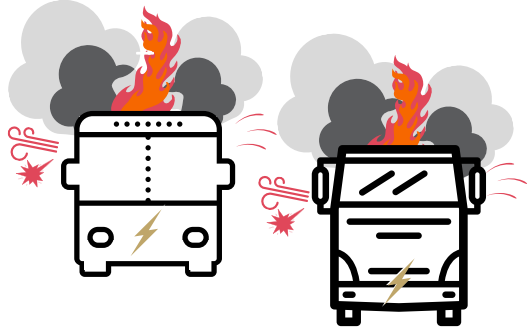


35
Battery fires

8
Injuries

4
Fatalities

Electric buses & trucks



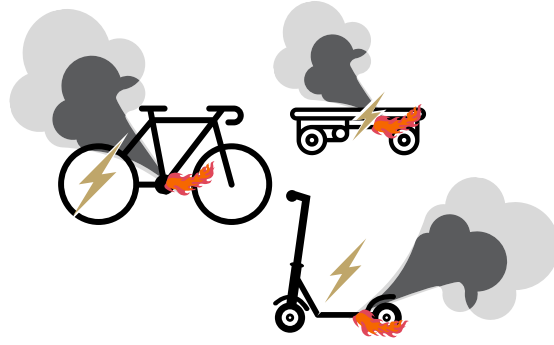
2
Battery fires

1
Battery fire

0
Injuries

0
Fatalities

Light electric vehicles



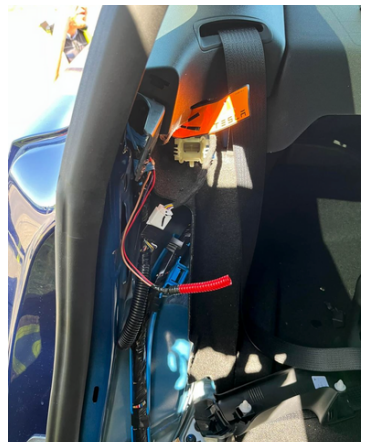
64
Battery fires

62
Injuries

21
Fatalities

New risks & challenges

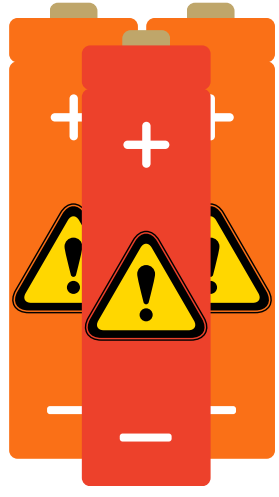
What do emergency responders know - & need to learn - to face EV ignition, vapour cloud explosion, electrocution & collision risks?



Two concepts

Battery pack construction

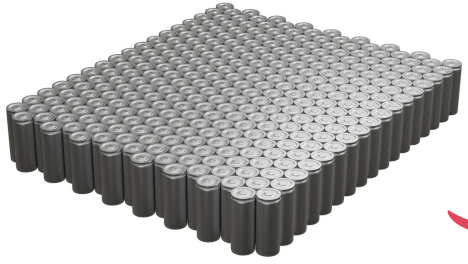
Thermal runaway



Battery pack construction

An EV HV traction battery pack is typically constructed like this:

Lithium ion battery cell

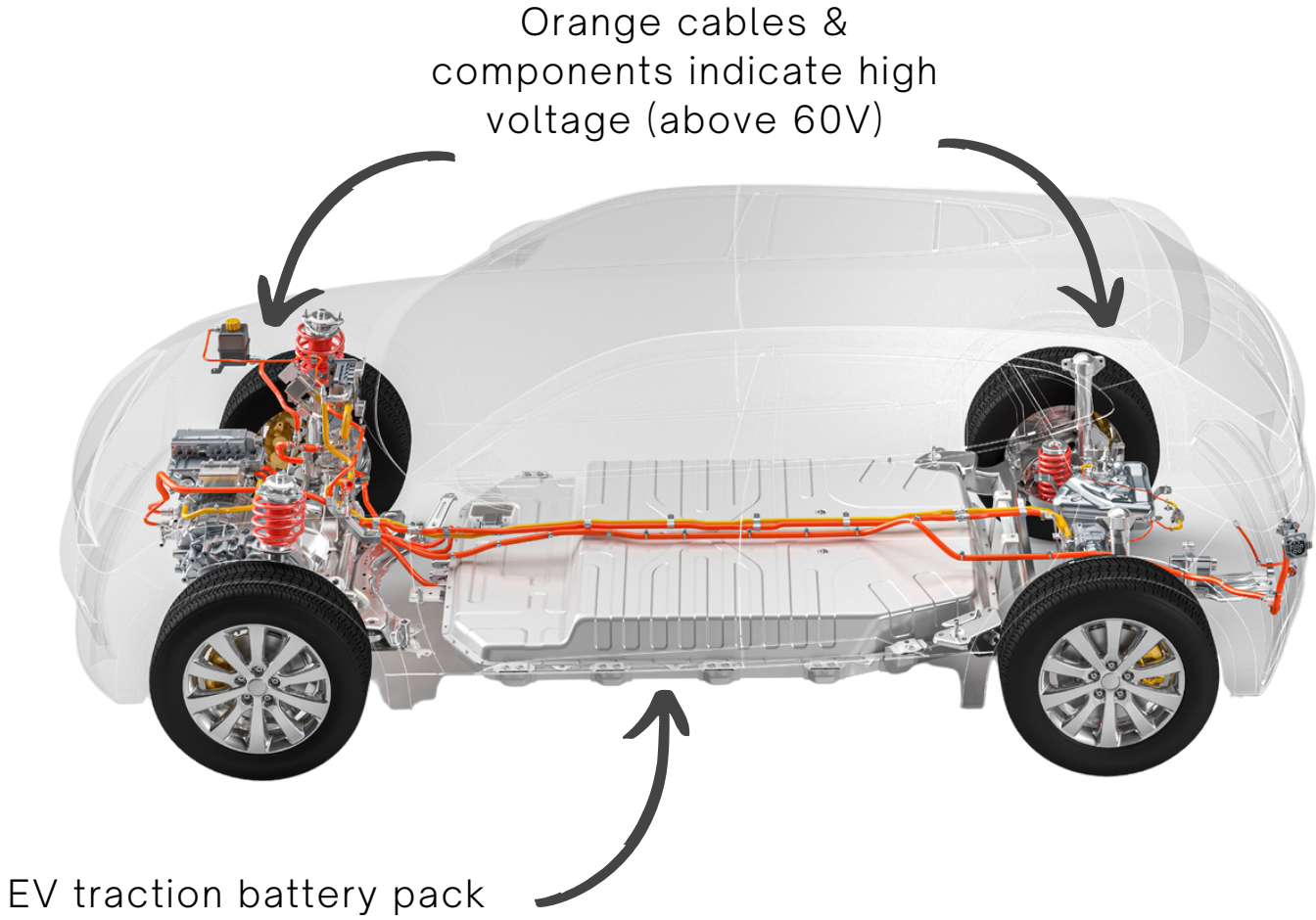


Multiple cells make a battery module

Multiple modules make a battery pack, which is enclosed in protective battery casings

Battery pack construction

In passenger EVs, the traction battery supplies power for vehicle momentum & is located beneath the vehicle, along the floor pan



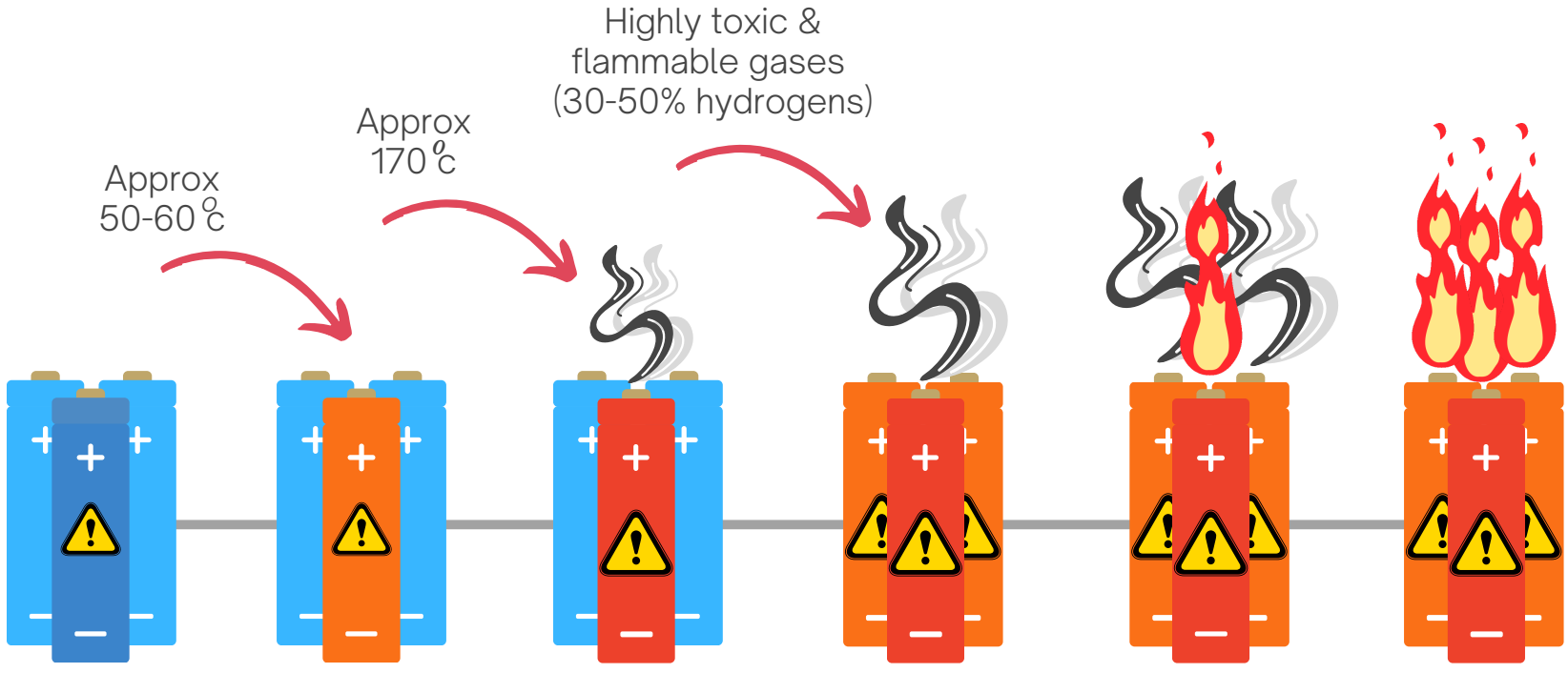
Thermal runaway

An **unstable chemical process** that is difficult to bring under control.

Click to view video on evfiresafe.com/ev-fire-what-is-thermal-runaway

Thermal runaway

Thermal runaway occurs when a battery cell suffers abuse, short circuits, heats up & bursts.



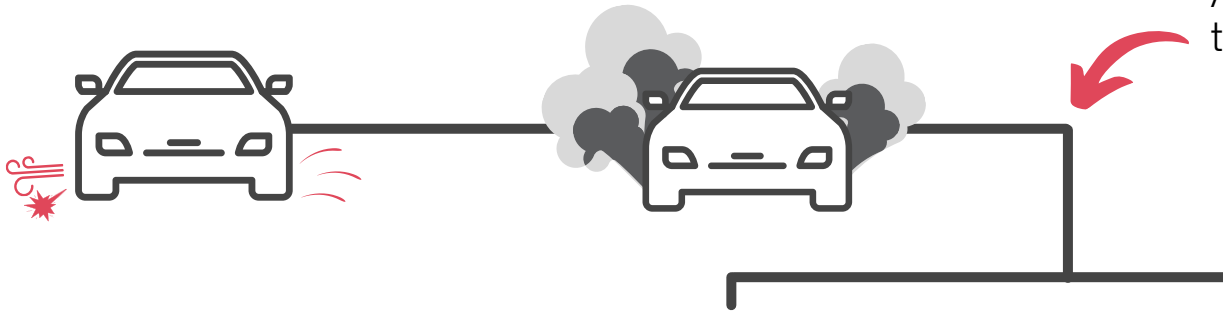
Early warning signs

From an emergency responder perspective, thermal runaway looks & sounds like this

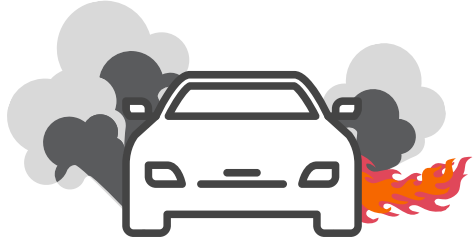
Popping - gunshots
Hiss/whistle - gas venting
'Cherry bubblegum' smell
Projectiles - cell debris

Dark vapour cloud,
light vapour cloud
(it's NOT smoke)

At this point, one of two things will occur



Ignition
Jet like, directional flames



~95%

Vapour cloud explosion
Violent deflagration

~5%

Electric Eco car on fire problem burn damage hybrid ev byd etron tesla problem in battery charger

Share

Click to view video on https://www.evfiresafe.com/ev-fire-behaviour

Vapour cloud explosion

Total of 20 **VCE incidents** globally since 2010:

70%

Underground / enclosed space

30%

Open air

4 incidents verified of:

- vapour cloud explosion
- in an enclosed space
- while connected to energised charging

Vapour cloud explosion

Click to view video on https://www.evfiresafe.com/post/electric-car-explosions

Vapour cloud explosion

Click to view video on https://www.evfiresafe.com/post/electric-car-explosions

What is the RotW doing?

We went to Norway, Netherlands, Germany & the UK to find & share knowledge

European conferences

Listening to & meeting with the world's leading scientists, researchers, firefighters & SMEs

- Battery Tech Expo
- London Fire Brigade
- National Fire Chief's Council

- Fires in Vehicles Conference
- International Symposium on Tunnel Safety & Security
- Nordic EV Expo
- Rogaland Fire Brigade

- Institute of Public Safety (NIPV)
- Schipol International Airport Fire Brigade
- DAF Trucks manufacturing plant
- Elaad NL
- Bussum Fire Brigade
- NL Towing Association

- Allianz Global Automotive Centre of Excellence
- Stellantis - Opel Manufacturing Plant
- Electromobility Safety Conference

What we learned...

No or limited testing & research

Some testing & research providng early answers, but more needed

Good results emerging, more to come

Testing done, answers widely accepted by SMEs & FR agencies

- Fire cause
- Risks & hazards (Incl vapour cloud explosion
- Suppression
- Tools & products

- Efficacy of PPE/PPC
- Decon of PPE/PPC
- Electrocution risk

- Impact on structures
- Impact in enclosed spaces

- Air quality
- Water runoff contamination

- Enhanced safety around charging hubs
- Early detection
- Electrocution risk

- EVs & LiBs at sea
- Remote area management
- Car stacker systems

EV battery fire suppression

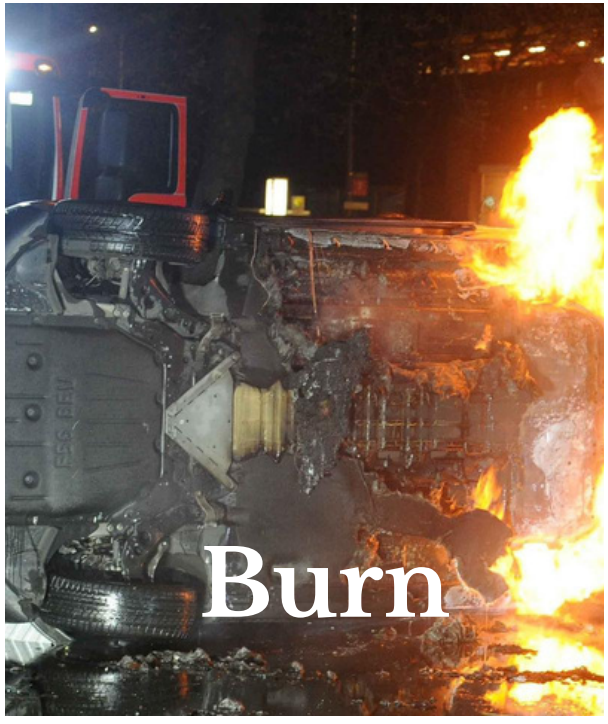
EV fire suppression

Three best practice options in use globally

Cool

Recommended by all EV manufacturers

Like 'putting out a kitchen fire by spraying water on the roof'



Burn

Accepted by some EV manufacturers

Removes stranded energy & secondary ignition risk

Submerge

Accepted by some EV manufacturers

Cools battery, contains fire spread, must be left >10 days

The Netherlands

Following difficult incidents like this, the Dutch use containers for effective carriage of totally destroyed EVs.

Submersion case study

- A BMW EV was suspected of thermal runaway & submerged insitu
- The container stood for 8 days in a residential neighbourhood
- 7,500 litres of polluted water had to be disposed of at a cost of ~AU$52,500

Cutting

We've always known that getting water into a battery pack can manage a battery fire quickly, but recent Swedish tests have proven that.

Image: CTIF

Cutting into EV battery packs

We've always known that getting water into a battery pack can manage a battery fire quickly, Swedish tests have proven that.

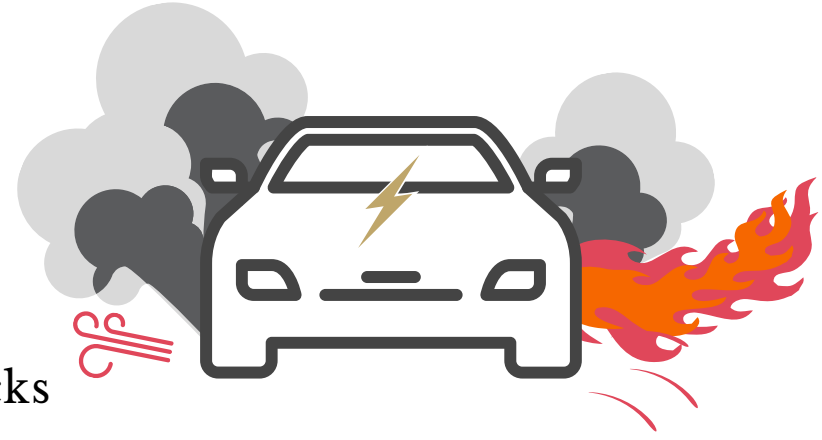
Video: CTIF

Cutting into EV battery packs

We - & many others - won't recommend cutting because:

Increased risk to responders

- Electrocution
- Standing in path of jet flames
- May cause thermal runaway



Space & expense

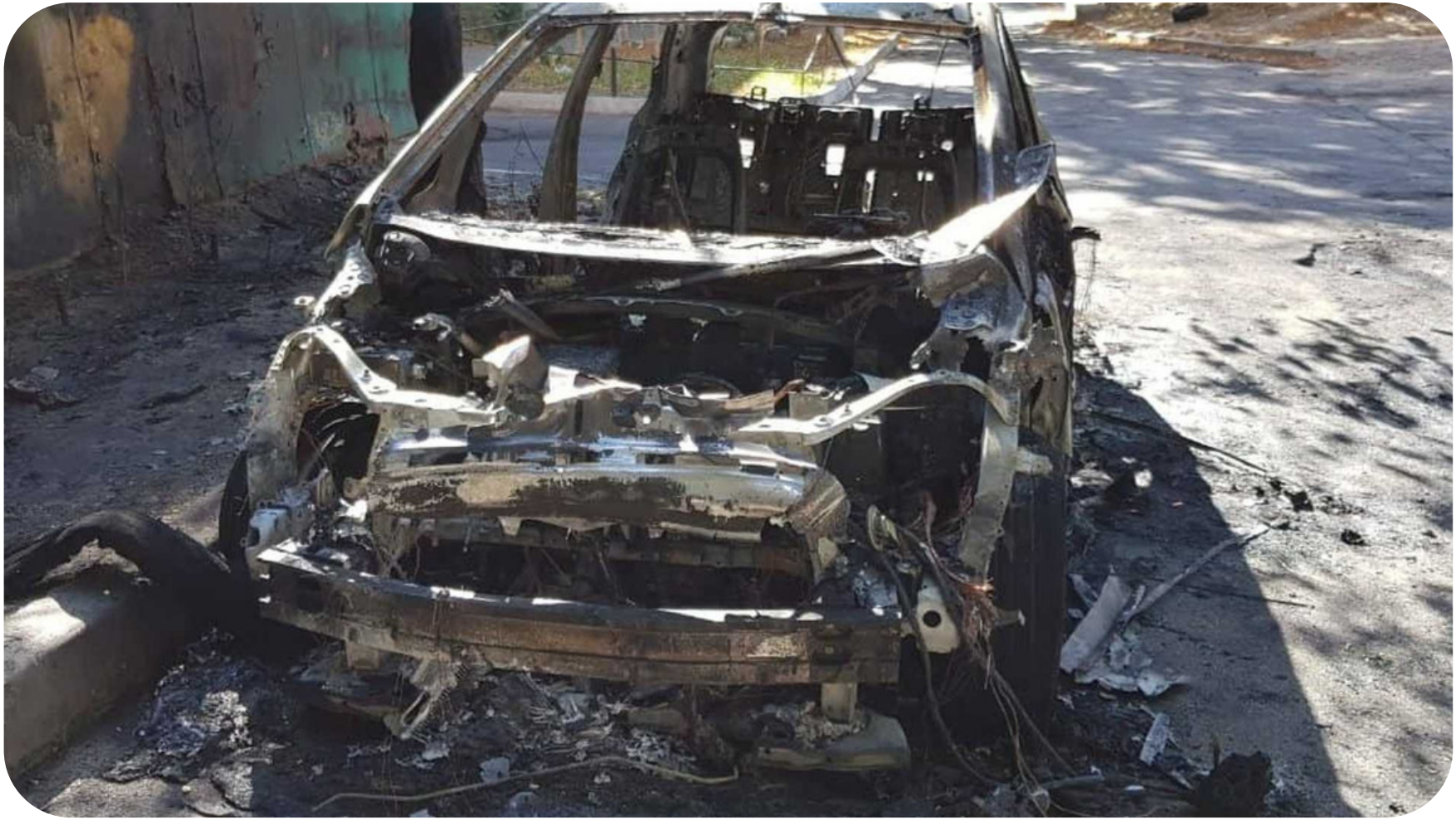
- ~ US$65,000, limited space on fire trucks

Current & future OEM innovation

- Model 3 & Y drop out pack
- Model Y cell to pack 'glue'
- FF Access Ports in some brands

No EV manufacturer recommends cutting into a HV pack in their emergency response guides.
<u>Many actively discourage it</u>

Valid option...

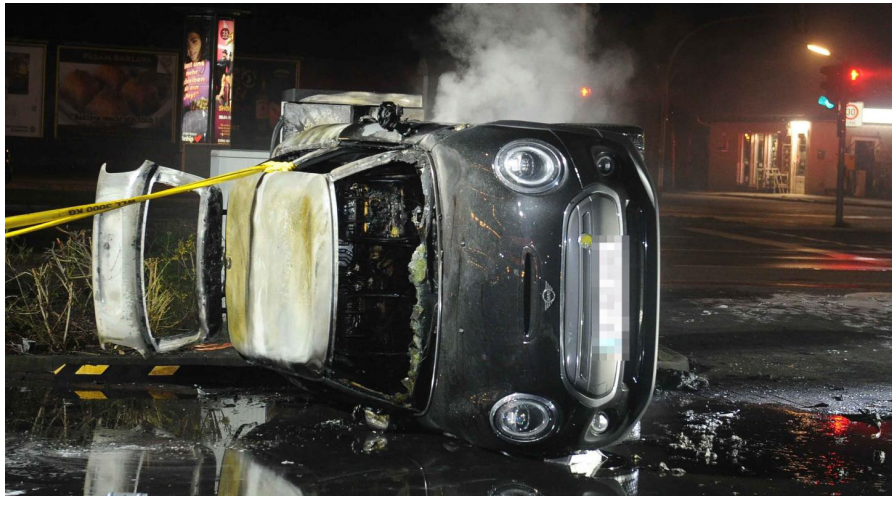


Can it burn out?

22 April 2022, Berlin, Germany

Electric Mini, possible technical defect, crews let EV burn out & flipped on side to observe

Source: spreepicture



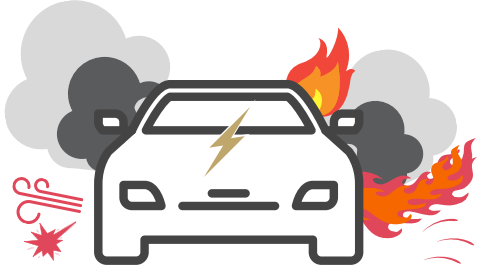

LHF 3200/1

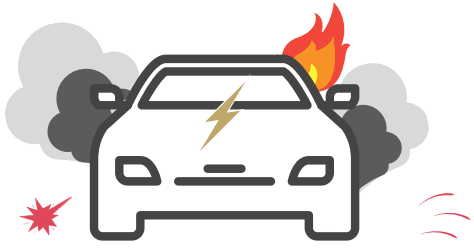

FEUERWEHR
MAN

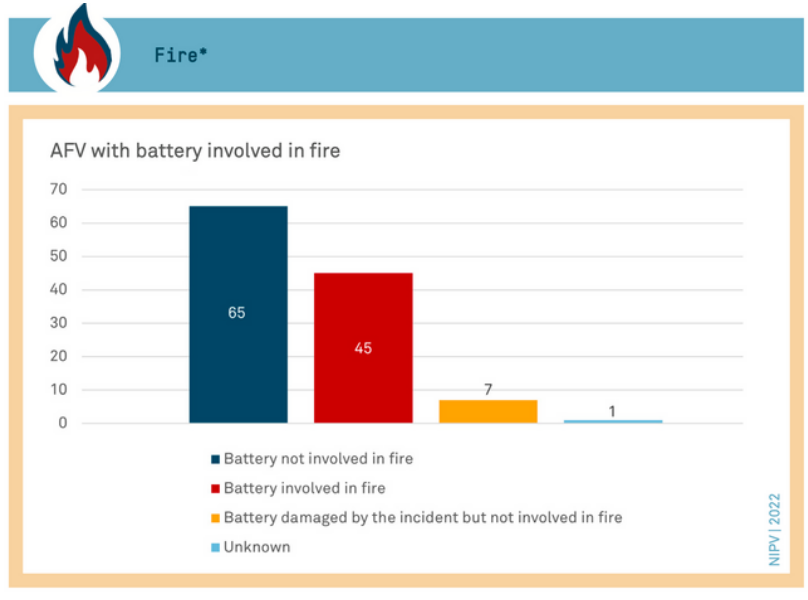
In over 50% of incidents
EV fire ≠ EV battery fire

EV fires vs EV battery fires

Early data indicates less than half of electric vehicles on fire involve the high voltage lithium-ion battery







Of all 2022 EV fires in Netherlands, only

38% involved the HV battery

NIPV (Netherlands)


LHF 3200/1
FEUERWE

Fire spread - multi EVs

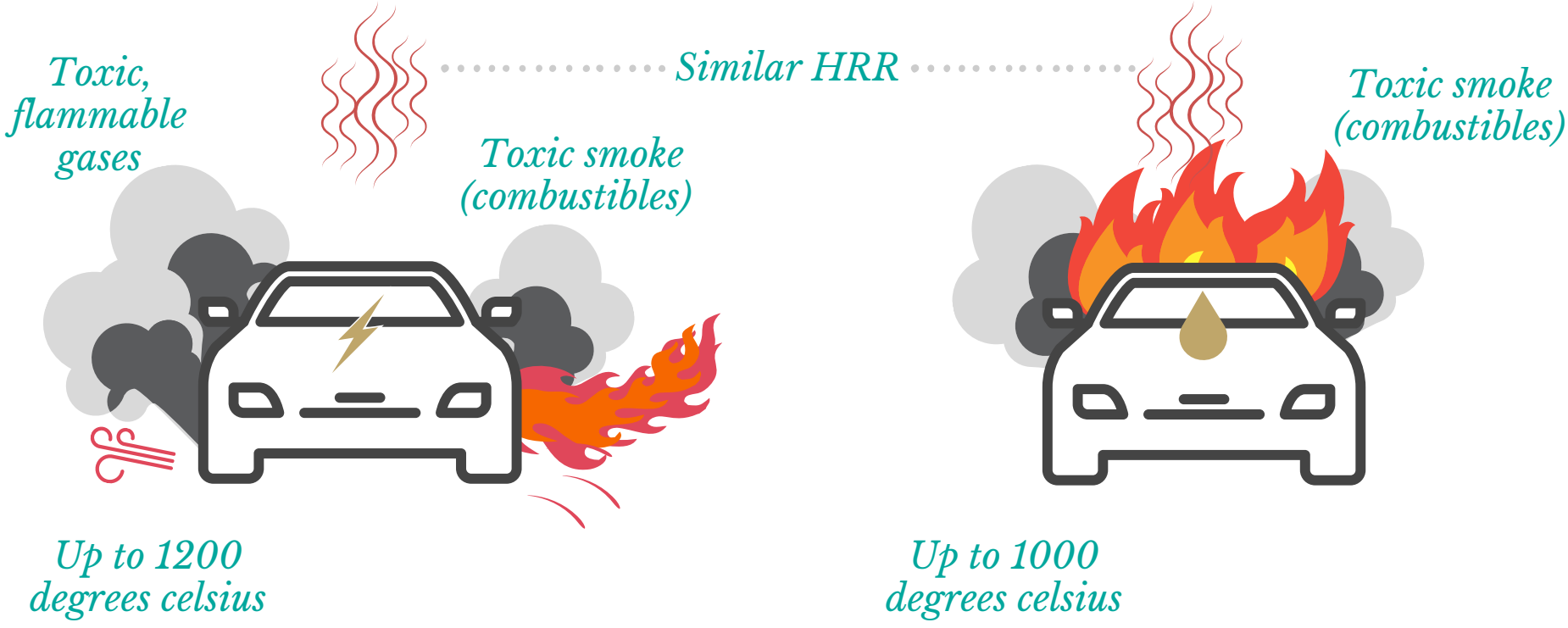
Early data may suggest that LiBs do not necessarily go into thermal runaway in ALL EVs during multi-EV incidents

Damage to structures can be similar to ICEV fires

EV vs ICEV: Similarities

Early testing indicates similar toxicity, heat release rate (rate at which fire releases energy) & temperature between vehicle types.

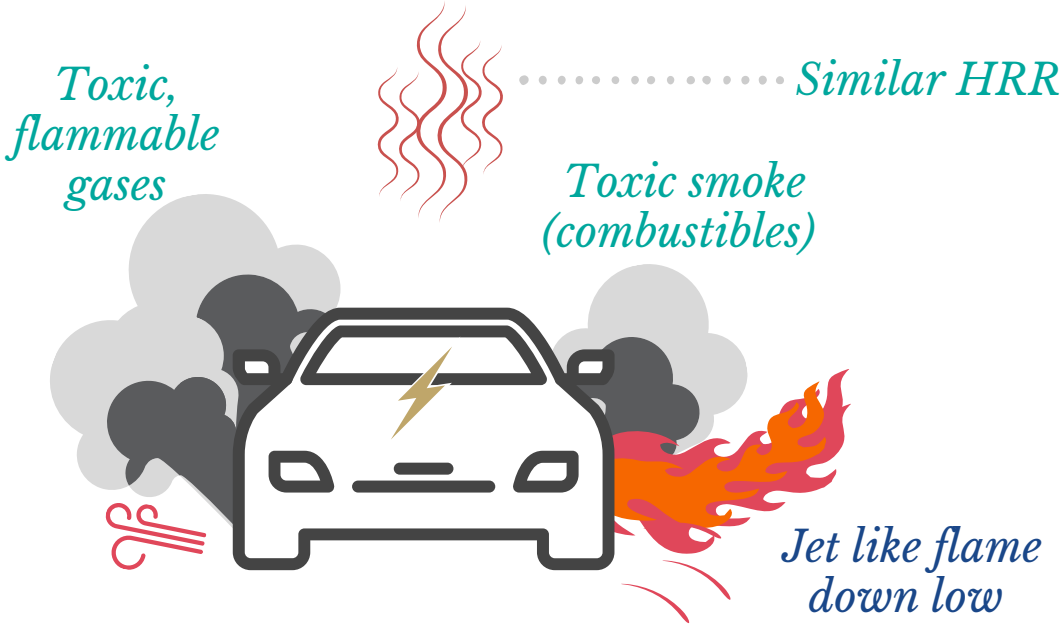
evfiresafe.com



EV vs ICEV; Differences

EVs have a different fuel source (HV battery vs fuel tank), incident duration & pose a secondary ignition risk.

evfiresafe.com



Similar HRR

Up to 1200 degrees celsius

Incident duration ~3-5 hours

Fire fuelled by a lithium-ion battery
Potentially explosive environment

Up to 1000 degrees celsius

Incident duration ~30 minutes

Fire fuelled by fuel tank & plastics

Case study

An arson attack on an ICEV & EV in the Singel Garage in the Netherlands is the closest we have to real-world data

Citroen C3 ICEV

Hyundai Ioniq BEV

Case study

No smoke ventilation in carpark, therefore crews could not find vehicles due to lack of visibility. Little to no heat was detected & TICs could not 'see' through smoke & vapour. Carpark was manually vented by fire crews.

Ceiling spalling above
Citroen C3 ICEV

Ceiling spalling above
Hyundai Ioniq BEV

What about training & SOPs?

Very little exists...globally

Some peak bodies have published guidance, but no fire agency has released approved SOPs or training. We put a global call out & have started to collate documents on our website.

Guidance

- Institute for Public Safety (Netherlands)
- Norwegian Directorate for Civil Protection (DSB)
- Danish Emergency Management Agency
- Australian Fire Agencies Council (AFAC)
- Department of fire brigades assistance fire protection (Germany)

Training

- UL's Fire Safety Research Institute (US) - BESS
- NFPA Alternative Fuelled Vehicles Online Training for Emergency Responders (USA)
- Fire Emergency New Zealand online training

- Various FDs globally creating ad-hoc training packs & info

Published SOPs

- Fire Emergency New Zealand?

- Various FDs globally creating ad-hoc SOPs, often based on first hand experience

LiB categorisation

Depending on LiB types, emergency response may differ.
We created the following to assist departments buildings SOPs.

Smaller Devices

Light EV (LEVs)

Road registered EV (EVs)

Battery energy storage systems (BESS)

New category, high risk?

Road registered light electric vehicles; not quite a car, not quite an e-bike. Used for cleaning, housekeeping, small deliveries.

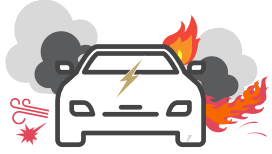
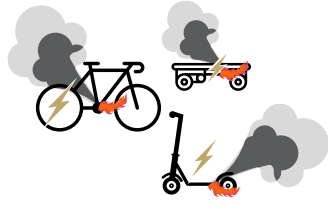
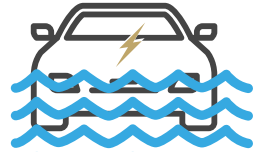
Emerging risk

Picnic Supermarkets use Goupil e-vans in Europe, with ~25 seperate thermal runaway events in 2 years, with the total loss of 3 depot buildings

LiB categorisation - updated

Category	Smaller Devices	Light EV (LEVs)	Light delivery EV (LDEV)	Road registered EV (EVs)	Battery energy storage systems (BESS)
					
OEM guidance	No ERG	No ERG	No ERG	Some ERGs available	Some ERGs available
Risk	Low risk	High risk	High risk	Very low risk	Very low risk
Response	Submerge	Submerge	Cool - water on HV pack	Cool Burn Submerge	Protect exposures Burn

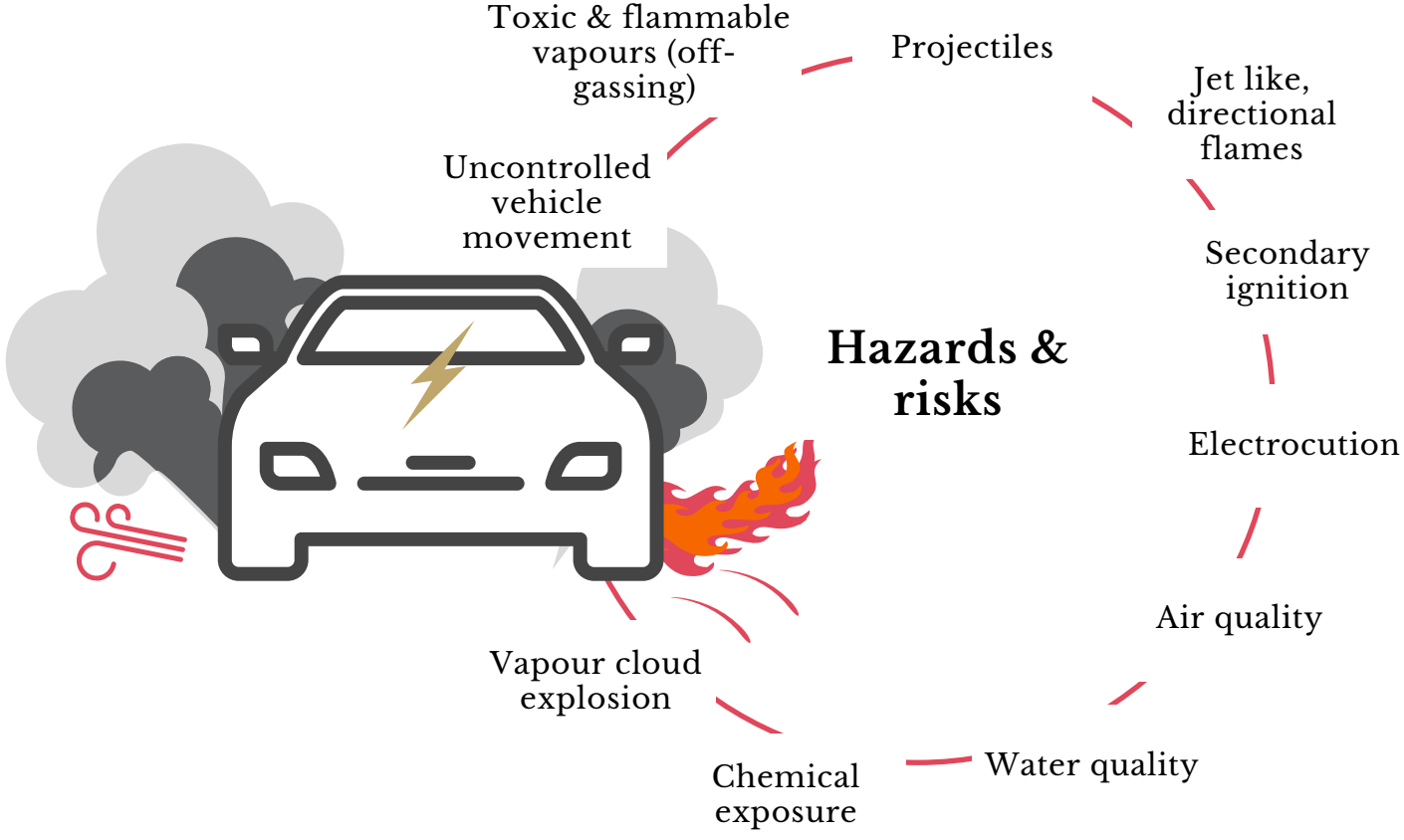
Training priorities (our 2 cents...)

1	2	3	4	5
EV road traffic collisions	EV battery fires	LEV battery fires	EVs submerged	Battery Energy Storage Systems
				
Common Low risk	Very rare Moderate risk	Common Very high risk	Uncommon Moderate risk	Uncommon Moderate risk

Road traffic collisions

Frefighters & emergency responders concerns:

- New hazards & risks
- Longer incident duration
- No established methods
- No training



Identify, Immobilise, Isolate

Basis of SOPs & training in development.
Go to: evfiresafe.com/ev-extrication

Thermal runaway DRA

1. Identify
2. Immobilise
3. Isolate

Assess

ERG
Approach
Exposures

Monitor

EV FireSafe next steps

EV walkaround videos

Fast & informative; how to Identify, Immobilise & Isolate an EV

- We've filmed with Tesla - release mid-June
- Planning for Hyundai, Kia, MG, Polestar, Nissan & ACTFR new electric fire truck

Global webinar series

Aims to share knowledge of real-world incidents & connect responders from all countries.

12 webinars being planned:

1. EV LiB fires & emergency response
2. Where are LiBs used & what's coming?
3. LEVs & EVs - what's the difference?
4. ERGs & HV isolation
5. EV charging & emergency response
6. EV road rescue
7. EV fires - what's in the water & air?
8. Secondary & delayed ignition
9. EV Suppression - burn out or extinguish?
10. Products & tools
11. Second life batteries
12. Building SOPs

Webinar series partner (so far):

NFCC National Fire Chiefs Council

Paul Christensen LITHIUM ION SAFETY

IFV Instituut Fysieke Veiligheid

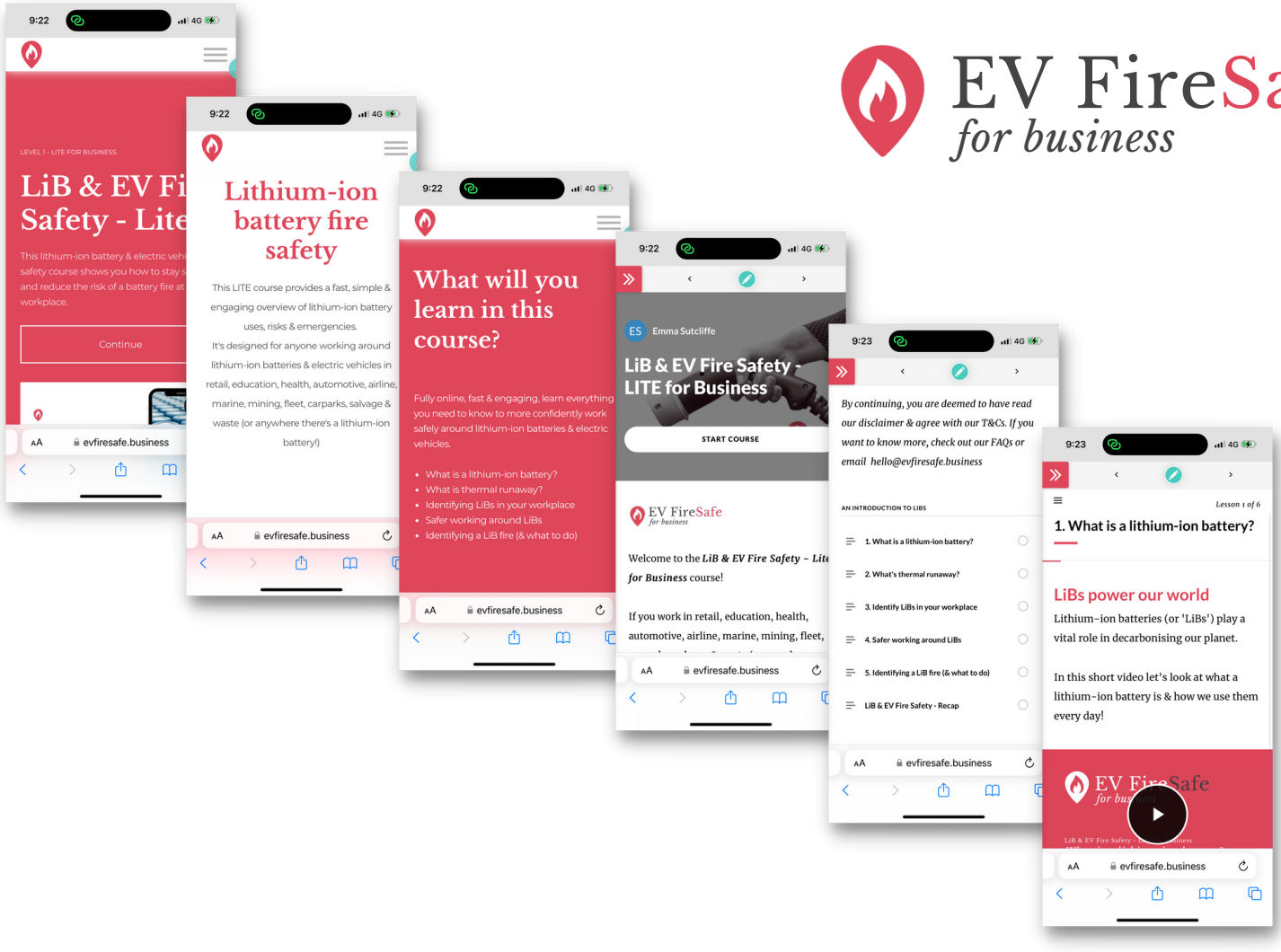
RI.SE

Anticipated reach:

At least 32 countries
Up to 25,000 responders per webinar
Up to 1 million responders via recorded webinars on YouTube & socials

Non-emergency training

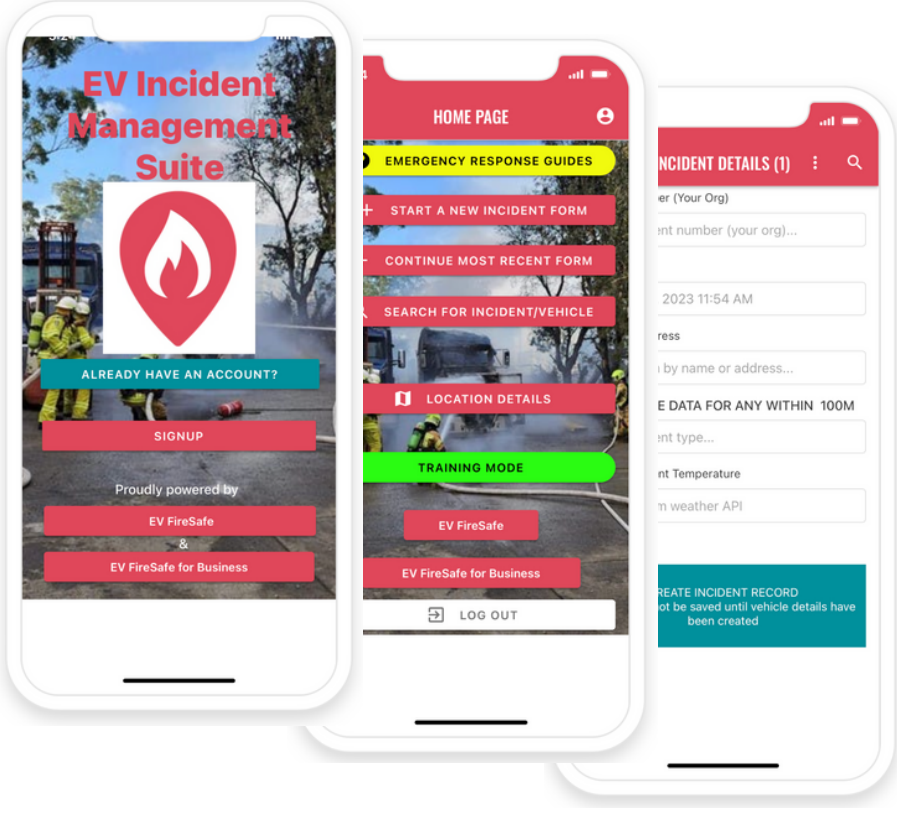
Online training for non-emergency sector



EV FireSafe
for business

LiB TRAKA App

We're developing an app to assist first & second responders, & non-emergency businesses manage a lithium-ion battery incident or fire.



The aim is to reduce risk to all parties managing a damaged LiB, from incident to wrecking, repair or disposal.

Brand new EV charging advice

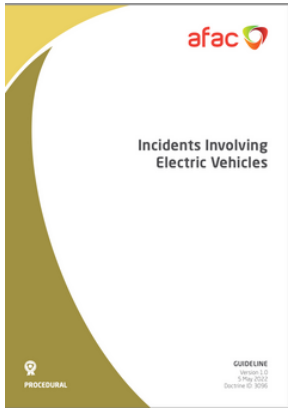
New Advisory Notice for EV charging sites from the Australian Building Code Board, released last week.

Useful (free) resources

evfiresafe.com

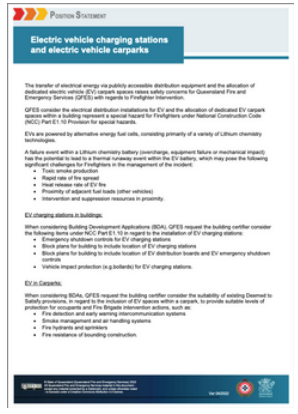
@evfiresafeproject

EV FireSafe

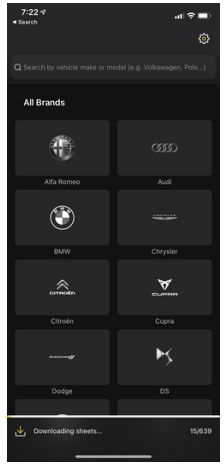


AFAC Incidents involving EVs

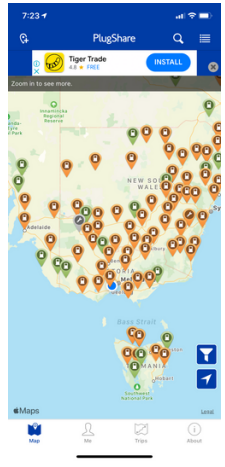
CFA Renewable Energy Facilities



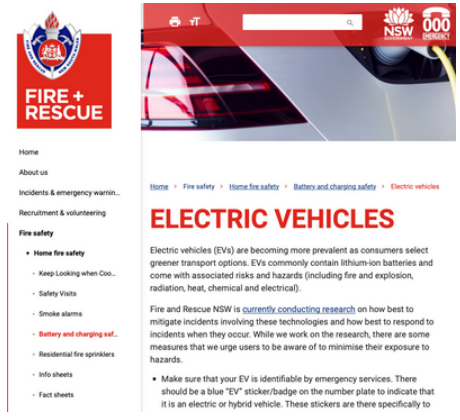
QFES EV Charging in Structures



ANCAP Rescue



PlugShare app



FRNSW Battery Advice

evfiresafe.com

Many thanks for your kind attention.

Emma Sutcliffe
Project Director
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0409 040 499

Scan with your smart phone camera to jump to the EVFS website